A SURVEYING INSTRUMENT

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a surveying instrument having a sighting telescope, and more specifically relates to a surveying instrument having a sighting telescope which is equipped with a device for preventing a ghost image from being formed in the field of view of the sighting telescope.

2. Description of the Related Art

A conventional surveying instrument such as a total station has a function to measure the distance between two points and also horizontal and vertical angles. Such a conventional surveying instrument generally measures the distance between two points with an electronic distance meter (EDM) incorporated in or attached to the surveying instrument. The electronic distance meter incorporates an optical distance meter which calculates the distance via the phase difference between projecting light and reflected light and via the initial phase of internal reference light, or via the time difference between the projecting light and the reflected light. The optical distance meter includes a light-transmitting optical system for transmitting a measuring light (projecting

light) to the target (sighting object) via the objective lens of a sighting telescope (collimating telescope) provided as a component of the electronic distance meter, and a light-receiving optical system for receiving light (reflected light) reflected by the target.

Among conventional surveying instruments having such an electronic distance meter, a surveying instrument whose electronic distance meter employs a prism having a dichroic mirror (wavelength selection mirror) that serves as a beam-splitting optical system is known in the art. Such a prism having a dichroic mirror is hereinafter referred to as a "dichroic prism". The dichroic mirror reflects light with specific wavelengths while allowing light with other wavelengths to pass through. The dichroic prism is disposed between the objective lens and the eyepiece of the sighting telescope so that the measuring light, which is emitted by a light emitting element, is reflected by the dichroic mirror of the dichroic prism to be projected toward the target (sighting object) via the objective lens of the sighting telescope. The light which is reflected by the target and passed through the objective lens is selectively reflected by the dichroic mirror to travel to a light-receiving element.

On the other hand, advancements have been made in the development of surveying instruments provided with a

sighting telescope having an autofocus system, wherein a phase-difference detection autofocus system is widely used. With this system, an in-focus state is detected based on the correlation between two images formed by two light bundles which are respectively passed through two different pupil areas of an objective lens of the sighting telescope.

The applicants of the present invention have proposed a surveying instrument in Japanese laid-open publication No.10-73772 (U. S. Patent No.5,877,892),in which one of the first through fourth reflection surfaces of a Porro prism is formed as a semitransparent mirror to divide the incident light path into two optical paths: a first optical path for the phase-difference detection autofocus system, and a second optical path for the sighting telescope.

However, in the above described conventional surveying instruments having a sighting telescope, especially with a Porro prism, a ghost image (or a flare spot), which is caused by off-field light (non-image forming light), is seen through the eyepiece of the sighting telescope. If such off-field light enters the autofocus system via the aforementioned semitransparent mirror, the performance of the autofocus system deteriorates.

SUMMARY OF THE INVENTION

An object of the present invention is to provide a a surveying instrument, wherein the performance of each of the sighting telescope and the focus detecting device of the surveying instrument is fully utilized by preventing a ghost image from being formed in the field of the sighting telescope optical system.

To achieve the object mentioned above, according to an aspect of the present invention, a surveying instrument is provided, including a sighting telescope having an objective lens and an eyepiece; an erecting optical system functioning so that an image formed by the objective lens is viewed as an erect image through the eyepiece; and a light shield device, positioned in an optical path extending from an incident surface of the erecting optical system to an exit surface of the erecting optical system, for preventing an off-field light bundle which is incident on the erecting optical system from reaching the eyepiece.

In an embodiment, the light shield device includes a light shield mask or plate fixed to the incident surface of the erecting optical system.

In an embodiment, the light shield mask includes an aperture which allows image forming light to pass therethrough, the aperture being shaped so as to be

asymmetrical with respect to an optical axis incident on the incident surface of the erecting optical system.

In an embodiment, a first length of the aperture from the incident optical axis to a first side, at which an optical path length between the incident surface and a first reflection surface of the erecting optical system is shortest, is shorter than a second length of the aperture from the incident optical axis to a second side at which an optical path length between the incident surface and the first reflection surface is longest.

In an embodiment, the erecting optical system includes two cemented prisms, and wherein the light shield device includes a recessed portion formed on a common edge of the cemented surface of the two cemented prisms.

In an embodiment, the erecting optical system includes two cemented prisms, and wherein the light shield device includes a beveled surface formed on a common edge of the cemented surface of the two cemented prisms.

In an embodiment, the light shield device is formed by an extended portion of the erecting optical system on the incident surface thereof, the extended portion being deformed to extend toward the objective lens side so that the off-field light bundle which is reflected by a first reflection surface of the erecting optical system is prevented from being incident on a second reflection

surface of the erecting optical system and being allowed to exit from the erecting optical system via the extended portion.

In an embodiment, the erecting optical system includes a semitransparent film formed on a first reflection surface of the erecting optical system, wherein light incident on the first reflection surface is transmitted through the semitransparent film to proceed toward a focus detecting device which detects a focus state of the sighting telescope.

The erecting optical system can include a Porro prism or a roof prism.

According to another aspect of the present invention, a surveying instrument is provided, including a sighting telescope having an objective lens and an eyepiece; a semitransparent film positioned between the objective lens and the eyepiece; a focus detecting device which receives light which is passed through the semitransparent film to detect a focus state of the sighting telescope; and a light shield device, positioned in an optical path extending from the semitransparent film to the focus detecting device, for preventing an off-field light bundle which is incident on the semitransparent film from reaching the focus detecting device.

In an embodiment, the surveying instrument further

includes an erecting optical system functioning so that an image formed by the objective lens is viewed as an erect image through the eyepiece, the semitransparent film being formed on a reflection surface of the erecting optical system.

In an embodiment, the light shield device is a light shield mask fixed to an incident surface of the erecting optical system.

In an embodiment, the surveying instrument further includes a beam splitting prism which is provided separately from the erecting optical system and cemented to the semitransparent film, the light shield device being fixed to the beam splitting prism.

In an embodiment, the semitransparent film is formed on a first reflection surface of the erecting optical system, the beam splitting prism being cemented to the first reflection surface wherein the semitransparent film being positioned between the beam splitting prism and the first reflection surface.

In an embodiment, the semitransparent film is formed on a second reflection surface of the erecting optical system, the beam splitting prism being cemented to the second reflection surface wherein the semitransparent film being positioned between the beam splitting prism and the second reflection surface.

In an embodiment, the surveying instrument includes an erecting optical system functioning so that an image formed by the objective lens is viewed as an erect image through the eyepiece, and a beam splitting prism provided separately from the erecting optical system; wherein the semitransparent film is formed on the beam splitting prism.

In an embodiment, the light shield device is fixed to an exit surface of the beam splitting prism.

The focus detecting device can be a phase-difference detection focus detecting device or a contrast detecting focus detecting device.

The erecting optical system can include a Porro prism or a roof prism.

Preferably, the sighting telescope includes a focus adjustment lens positioned between the objective lens and the erecting optical system.

Preferably, the beam splitting prism includes a right-angle prism.

Preferably, the Porro prism includes three right angle prisms.

The present disclosure relates to subject matter contained in Japanese Patent Application No.2000-319117 (filed on October 19, 2000) which is expressly incorporated herein by reference in its entirety.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be described below in detail with reference to the accompanying drawings in which:

Figure 1 is a schematic drawing of an embodiment of an electronic distance meter having an focus detecting device, according to the present invention;

Figure 2 is a cross sectional view of fundamental optical elements of the electronic distance meter shown in Figure 1, taken along II-II line in Figure 1, viewed in the direction of the appended arrows;

Figure 3 is a plan view of a switching-mirror drive mechanism provided in the electronic distance meter shown in Figure 1, viewed in the direction of an arrow III in Figure 1;

Figure 4 is a conceptual diagram of the focus detecting device (AF sensor unit), as viewed in the direction of an arrow IV shown in Figure 1;

Figure 5 is a perspective view of the Porro prism and the focal-plane plate shown in Figure 1;

Figure 6 is an explanatory view illustrating off-field light in the electronic distance meter shown in Figure 1;

Figure 7 is an explanatory view illustrating the off-field light bundle shown in Figure 6;

Figure 8 is a fragmentary diagram of the electronic distance meter shown in Figure 1 and illustrates another off-field light bundle which travels in a different direction;

Figure 9 is a side elevational view of a fundamental portion of the electronic distance meter shown in Figure 1, illustrating the first embodiment of a ghost image formation preventing device according to the present invention;

Figure 10 is a front elevational view of a fundamental portion of the ghost image formation preventing device shown in Figure 9, as viewed in the direction of an arrow X shown in Figure 9;

Figure 11 is a side elevational view similar to that of Figure 9, illustrating the second embodiment of the ghost image formation preventing device according to the present invention;

Figure 12 is a perspective view of the Porro prism and the focal-plane plate shown in Figure 11;

Figure 13 is a side elevational view of another embodiment of a fundamental portion of the second embodiment of the ghost image formation preventing device shown in Figure 11;

Figure 14 is a side elevational view similar to that of Figure 9 and illustrates the third embodiment of the

ghost image formation preventing device according to the present invention;

Figure 15 is a perspective view of the Porro prism and the focal-plane plate shown in Figure 14;

Figure 16 is a side elevational view of another embodiment of a fundamental portion of the third embodiment of the ghost image formation preventing device shown in Figure 14;

Figure 17 is a side elevational view similar to that of Figure 9, illustrating the fourth embodiment of the ghost image formation preventing device according to the present invention;

Figure 18 is a perspective view of the Porro prism and the focal-plane plate shown in Figure 17;

Figure 19 is a side elevational view similar to that of Figure 9, illustrating the fifth embodiment of the ghost image formation preventing device according to the present invention;

Figure 20 is a plan view of a light shield mask provided in a Porro prism shown in Figure 19, viewed in the direction of arrows X in Figure 19;

Figure 21 is a plan view of another light shield mask provided in the Porro prism shown in Figure 19, viewed in the direction of arrows Y in Figure 19;

Figure 22 is a view similar to that of Figure 9 and

illustrates the sixth embodiment of the ghost image formation preventing device according to the present invention;

Figure 23 is a rear elevational view of a fundamental portion of the ghost image formation preventing device shown in Figure 22, viewed in the direction of an arrow P shown in Figure 22;

Figure 24 is a plan view of a light shield mask provided in a Porro prism shown in Figure 22, viewed in the direction of arrows Q in Figure 22;

Figure 25 is a plan view of another light shield mask provided in the Porro prism shown in Figure 22, viewed in the direction of arrows R in Figure 23;

Figure 26 is a side elevational view similar to that of Figure 9, illustrating the seventh embodiment of the ghost image formation preventing device according to the present invention;

Figure 27 is a side elevational view similar to that of Figure 26, illustrating the eighth embodiment of the ghost image formation preventing device according to the present invention;

Figure 28 is a plan view of a light shield mask provided in the Porro prism shown in Figure 22, viewed in the direction of arrows S in Figure 27;

Figure 29 is a perspective view of an embodiment of

a roof prism serving as an erecting optical system which can be replaced with the Porro prism used in each of the first through eighth embodiments of the ghost image formation preventing devices;

Figure 30 is a side elevational view of another embodiment of a fundamental portion of the first embodiment of the ghost image formation preventing device shown in Figure 9, showing the case where the Porro prism shown in Figure 9 is replaced by the roof prism shown in Figure 28;

Figure 31 is a side elevational view of another embodiment of a fundamental portion of the second embodiment of the ghost image formation preventing device shown in Figure 11, showing the case where the Porro prism shown in Figure 11 is replaced by the roof prism shown in Figure 28; and

Figure 32 is a side elevational view of another embodiment of a fundamental portion of the fifth embodiment of the ghost image formation preventing device shown in Figure 19, showing the case where the Porro prism shown in Figure 19 is replaced by the roof prism shown in Figure 28;

Figure 33 is a plan view of a light shield mask provided in the roof prism shown in Figure 32, viewed in the direction of arrows T in Figure 32.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Figure 1 shows an embodiment of an electronic distance meter (EDM) equipped with an autofocus system, according to the present invention. This electronic distance meter can be incorporated in or attached to a surveying instrument such as a total station. The electronic distance meter is provided with a sighting telescope (sighting telescope optical system) 10 and an optical distance meter 20. As shown in Figures 1 and 2, the sighting telescope 10 is provided with an objective lens 11, a focusing lens 12, a Porro prism (erecting optical system) 13, a focal-plane plate (reticle plate) 14, and an eyepiece 15, in that order from the object side (i.e., left to right as shown in Figure 1). The focal-plane plate 14 is provided thereon with a reticle (cross hair) 16. The focusing lens 12 is guided in the direction of an optical axis X of the sighting telescope 10. The image of a corner cube prism (i.e., a sighting object placed at a point of measurement) 17 that is formed through the objective lens 11 can be precisely focused on the front surface (the surface facing the objective lens 11) of the focal-plane plate 14 by adjusting the axial position of the focusing lens 12 in accordance with the distance of the corner cube prism 17 with respect to the

sighting telescope 10. The Porro prism 13 functions so that the image of the corner cube prism 17 is viewed as an erect image through the eyepiece 15. The user (surveyor) of the surveying instrument sights a magnified image of the corner cube prism 17, which is focused on the focal-plane plate 14, via the eyepiece 15.

The electronic distance meter is provided between the objective lens 11 and the focusing lens 12 with a cubic dichroic prism 21 that serves as a beam-splitting optical system. The dichroic prism 21 is constructed from two right-angle prisms which are cemented to each other. The dichroic prism 21 is provided with a dichroic mirror 21a (wavelength selection mirror) which is formed on a boundary surface between the two right-angle prisms. The dichroic prism 21 is an element of the optical distance meter 20, and is fixedly positioned behind the objective lens 11 via a fixing device (not shown). The dichroic prism 21 is provided therein with the aforementioned dichroic mirror 21a which reflects light with specific wavelengths while allowing others to pass therethrough. The dichroic prism 21 is positioned on the optical axis X so that the dichroic mirror 21a is inclined to a plane perpendicular to the optical axis X by 45 degrees.

The optical distance meter 20 is provided above the dichroic prism 21, in Figure 1, with a light-emitting

element (laser diode) 23. The light-emitting element 23 emits light (measuring light) having a specific wavelength within the range of wavelengths of the light which is reflected by the dichroic mirror 21a of the dichroic prism 21. The measuring light (externally-projecting light) emitted from the light-emitting element 23 is reflected by the dichroic mirror 21a to be projected toward the corner cube prism 17 via the objective lens 11. The light-emitting element 23 and the dichroic mirror 21a are elements of a light-transmitting optical system of the optical distance meter 20. The measuring light which is reflected by the corner cube prism 17 and passed through the objective lens 11 is reflected by the dichroic mirror 21a again. At this time, the wavelengths of the light bundles incident upon the dichroic mirror 21a, which are not within the range of wavelengths of the light which is reflected by the dichroic mirror 21a, pass through the dichroic mirror 21a.

A right-angle prism 22 which is an element of the optical distance meter 20 is disposed between the light-emitting element 23 and the dichroic prism 21. The right-angle prism 22 is positioned on one side (the upper side as viewed in Figure 3) of a plane F (see Figure 3) which includes the central axis of a light bundle incident on a light-receiving element 31 and the central axis of

a light bundle emitted from the light-emitting element 23. Accordingly, the portion of the light bundle, emitted from the light-emitting element 23, which does not interfere with the right-angle prism 22 is made incident on the dichroic mirror 21a of the dichroic prism 21. Thereafter, the measuring light which is reflected by the dichroic mirror 21a and incident on a reflection surface 22a of the right-angle prism 22 is reflected by the reflection surface 22a to be incident on the light-receiving element 31. The dichroic mirror 21a, the reflection surface 22a and the light-receiving element 31 are elements of a light-receiving optical system of the optical distance meter 20.

The electronic distance meter is provided with a switching prism 28 and a first ND filter 29 between the right-angle prism 22 and the light-emitting element 23, on a distance-measuring optical path. As shown in Figure 3, the switching prism 28 can rotate about a pivot 28a between an advanced position (the position shown by a two-dot chain line in Figure 3) and a retracted position (the position shown by a solid line in Figure 3). The light emitted by the light-emitting element 23 is incident on a first fixed mirror 24a and is reflected thereby to be incident as an internal reference light on the light-receiving element 31 via a second fixed mirror 24b when

the switching prism 28 is positioned in the advanced position. On the other hand, the light emitted by the light-emitting element 23 is incident directly on the dichroic prism 21 when the switching prism 28 is positioned in the retracted position. The first ND filter 29 is used to adjust the amount of the measuring light incident on the corner cube prism 17.

The electronic distance meter is provided between the right-angle prism 22 and the light-receiving element 31, on a distance-measuring optical path, with a second ND filter 32 and a band-pass filter 34, in that order from the right-angle prism 22 to the light-receiving element 31. The light-receiving element 31 is connected to a controller (calculation control circuit) 40. The controller 40 is connected to an actuator 41 which drives the switching prism 28, and an indicating device (e.g., an LCD panel) 42 which indicates the calculated distance.

As known in the art, the optical distance meter 20 establishes two different states: one state wherein light emitted by the light-emitting element 23 is supplied to the dichroic prism 21 as the measuring light, and another state wherein the light is supplied to the fixed mirror 24a as the internal reference light, which are determined in accordance with the switching state of the switching prism 28 driven by the controller 40 via the actuator 41.

As described above, the measuring light supplied to the dichroic prism 21 is projected toward the corner cube prism 17 via the dichroic mirror 21a and the objective lens 11, and the measuring light reflected by the corner cube prism 17 is incident on the light-receiving element 31 via the objective lens 11, the dichroic mirror 21a, the reflection surface 22a, the second ND filter 32 and the band-pass filter 34. The controller 40 detects the phase difference between the projecting light and the reflected light, and the initial phase of the internal reference light which is supplied to the light-receiving element 31 via the switching prism 28, the first fixed mirror 24a, and the second fixed mirror 24b, or the time difference between the projecting light and the reflected light, to calculate the distance from the electronic distance meter to the corner cube prism 17. The calculated distance is indicated by the indicating device 42. Such an operation of calculating the distance is well known in the art.

The present embodiment of the electronic distance meter is provided with a phase-difference detection AF sensor unit (phase-difference detection focus detecting device) 50 which is positioned appropriately with respect to the light path reflected by a reflection surface of the Porro prism 13. As shown in Figure 5, the Porro prism 13 is of a type which employs three right angle prisms having

six rectangular surfaces: an incident surface 13a, first through fourth reflection surfaces 13b, 13c, 13d and 13e, and an exit surface 13f, in that order from the incident light side. A semitransparent film is formed on the first reflection surface 13b so as to serve as a semitransparent mirror. The incident surface 13a extends perpendicular to an optical axis 13X (of the focusing lens 12) incident on the incident surface 13a. A portion of the light incident on the incident surface 13a is reflected downwards by the first reflection surface 13b at an angle of 90 degrees. The light reflected by the first reflection surface 13b is reflected by the second reflection surface 13c so that the optical axis reflected from the second reflection surface 13c extends normal (i.e., at an angle of 90 degrees in a direction to the left as viewed in Figure 4) to a plane defined by the optical axis incident on the first reflection surface 13b and the optical axis incident on the second reflection surface 13c. The light reflected by the second reflection surface 13c is reflected upwards by the third reflection surface 13d at an angle of 90 degrees. The light reflected by the third reflection surface 13d is reflected rearwards by the fourth reflection surface 13e at an angle of 90 degrees to proceed in a direction parallel to the incident light on the incident surface 13a. The light reflected by the

fourth reflection surface 13e exits from the exit surface 13f to be incident on the focal-plane plate 14. The exit surface 13f extends perpendicular to an optical axis 13Y emerging from the exit surface 13f. The eyepiece 15 is positioned on the optical axis 13Y.

A beam splitting prism (a right-angle prism) 18 is cemented to the semitransparent film formed on the first reflection surface 13b. The right-angle prism 18 is provided with an incident surface 18a, a reflection surface 18b and an exit surface 18c. The incident surface 18a is cemented to the semitransparent film formed on the first reflection surface 13b. The reflection surface 18b extends perpendicular to the incident surface 18a and reflects the incident light thereon upwards, normal to the exit surface 18c. The light reflected by the reflection surface 18b exits from the exit surface 18c to proceed toward the AF sensor unit 50. Accordingly, the light which is passed through the first reflection surface 13b and the incident surface 18a is projected toward the AF sensor unit 50 via the reflection surface 18b and the exit surface 18c, while the light which is reflected by the first reflection surface 13b is projected toward the eyepiece 15 via the second, third and fourth reflection surfaces 13c, 13d and 13e, and the exit surface 13f of the Porro prism 13.

Figure 4 shows a conceptual diagram of the AF sensor unit 50. A reference focal plane 51 is provided between the Porro prism 13 and the AF sensor unit 50, and is located at a position optically equivalent to the position at which the reticle 16 of the focal-plane plate 14 is placed. The AF sensor unit 50 detects the focus state (amount of defocus and direction of focal shift) on the reference focal plane 51. The AF sensor unit 50 includes a condenser lens 52, a pair of separator lenses 53, and a pair of line sensors (e.g., multi segment CCD sensors) 54 located behind the respective separator lenses 53. The pair of separator lenses 53 are arranged apart from each other by the base length. The image of the corner cube prism 17 formed on the reference focal plane 51 is separated into two images by the pair of separator lenses 53 to be respectively formed on the pair of line sensors 54. Each of the pair of line sensors 54 includes an array of photoelectric converting elements. Each photoelectric converting element converts the received light thereon into electric charges which are integrated (accumulated), and outputs as an integrated electric charge to the controller 40 to constitute AF sensor data. The controller 40 calculates an amount of defocus through a predetermined defocus operation in accordance with a pair of AF sensor data respectively input from the pair of line

sensors 54. In an autofocus operation, the controller 40 drives the focusing lens 12 to bring the corner cube prism 17 into focus via a lens drive motor 19 (see Figure 1) in accordance with the calculated amount of defocus. The defocus operation is well-known in the art. An AF start switch 44 and a distance-measurement operation start switch 45 are connected to the controller 40.

The AF sensor unit 50 detects an in-focus state from the pair of images respectively formed on the pair of line sensors 54 by two light bundles 11A and 11B which are respectively passed through two different pupil areas (not shown) on the objective lens 11. The shape of each of the two pupil areas can be determined by the shape of the aperture formed on corresponding one of a pair of separator masks 55 which are respectively positioned in the vicinity of the pair of separator lenses 53 between the condenser lens 52 and the pair of separator lenses 53.

Figures 6 and 7 are explanatory views similar to those of Figures 1 and 5 in regard to off-field light (non-image forming light) which causes a ghost image (or a flare spot). If an off-field light bundle 60, a principal ray of which is shown by one-dot chain line in Figure 6, is incident on the objective lens 11 at a point on the front surface thereof in the vicinity of the maximum effective aperture of the objective lens 11, and is

subsequently incident on the incident surface 13a of the Porro prism 13 in the vicinity of an end of the incident surface 13a by a specific angle in a manner as shown in Figure 6, the off-field light bundle 60 is reflected by the first reflection surface 13b to return to the incident surface 13a. This returned off-field light bundle 60 is totally reflected by the incident surface 13a to form an image on the focal-plane plate 14 in the vicinity of the center thereof. This image is seen as a ghost image in the field of view of the sighting telescope 20 via the eyepiece 15. The ghost image tends to be seen easily especially when the intensity of the off-field light bundle 60 is high. A principal ray of a central light bundle 63 which is incident on the front surface of the objective lens 11 along the optical axis thereof and is subsequently incident on the incident surface 13a of the Porro prism 13 at the center thereof is shown in Figure 5 for comparison with the off-field light bundle 60.

In a state where the first reflection surface 13b does not split the incident light (i.e., if semitransparent film is not formed on the first reflection surface 13b), the image-forming light traveling in the field of the sighting telescope optical system is totally reflected by the first reflection surface 13b since the image-forming light is incident on the first reflection

surface 13b at an angle equal to or greater than the critical angle (e.g., approximately 41 degrees in the case of using BK7), while the off-field light bundle 60 mostly passes through the first reflection surface 13b (approximately five percent of the off-field light bundle 60 is reflected by the first reflection surface 13b) since the off-field light bundle 60 is incident on the first reflection surface 13b at an angle smaller than the critical angle. Therefore, the off-field light bundle 60 has little effect on the object image seen through the eyepiece. However, with the semitransparent film on the first reflection surface 13b, the reflectivity of the first reflection surface 13b increases. For example, even if the off-field light bundle 60 is incident on the first reflection surface 13b at an angle smaller than the critical angle, due to the increased reflectivity of the first reflection surface 13b, it is possible for the off-field light bundle 60 to be reflected thereby. If the Porro prism 13 is sufficiently large with respect to the effective aperture of the objective lens 11, the off-field light bundle 60 can be reflected by one or more sides of the Porro prism 13 but does not enter the field of the sighting telescope optical system. However, surveying instruments are required to be compact and easy to carry, which inevitably miniaturizes the Porro prism 13. If the

Porro prism 13 is small in size, an off-field light bundle which travels in a specific direction is totally reflected by the incident surface 13a of the Porro prism 13 after having been reflected by the first reflection surface 13b thereof to be formed as a ghost image seen through the eyepiece. As a result, two images overlap each other to thereby deteriorate the performance (e.g., a resolution) of the sighting telescope. Moreover, the off-field light bundle 60 which partly passes through the first reflection surface 13b and reaches the AF sensor unit 50 has the adverse effect of deteriorating the precision of the AF sensor unit 50.

Figure 8 shows a principal ray of another off-field light bundle 61 which travels in a direction different from that of the above described off-field light bundle 60 to discuss problems of the off-field light bundle 61. The off-field light bundle 61 is incident on the Porro prism 13 in a direction which is symmetrical to the direction of the off-field light bundle 60 with respect to the optical axis X. The off-field light bundle 61 is repeatedly reflected by a side 13g of the Porro prism 13, and therefore has little effect on the object image seen through the eyepiece 15. However, it is preferable that such reflections of the off-field light bundle 61 not exist. Each of all the sides of the Porro prism 13 except the

incident surface 13a, the first and fourth reflection surfaces 13b through 13e and the exit surface 13f is preferably formed as a matt surface.

Specific problems for the case where the first reflection surface 13b of the Porro prism 13 is formed as a semitransparent mirror used for detecting a focus have been discussed above. However, even if the Porro prism 13 is not provided with a semitransparent mirror (i.e., even if the electronic distance meter is not provided with a focus detection system), an off-field light bundle sometimes causes a ghost image. In addition, if there is an object which gives off light of a high intensity, an adverse effect in the field of view of the sighting telescope occurs if one of the reflection surfaces of the Porro prism 13, except the first reflection surface 13b thereof, is formed as a semitransparent mirror serving as a beam splitter.

The present embodiment of the electronic distance meter is equipped with a ghost image formation preventing device for preventing the formation of the above described ghost images. More specifically, the present embodiment of the electronic distance meter is provided, in an optical path extending from the incident surface 13a to the exit surface 13f of the Porro prism 13, with a light shield device for preventing off-field light bundles which is

incident on the Porro prism 13 from reaching the AF sensor unit 50, or is provided, in an optical path extending from the first reflection surface 13b to the AF sensor unit 50, with a light shield device for preventing off-field light bundles which is incident on the first reflection surface 13b from reaching the AF sensor unit 50.

Figures 9 through 21 show the first through six embodiments of the ghost image formation preventing devices. In each of these embodiments, a semitransparent film is formed on the first reflection surface 13b so as to serves as a semitransparent mirror. More specifically, the beam splitting prism 18 is cemented to the semitransparent film formed on the first reflection surface 13b.

Figures 9 and 10 show the first embodiment of the ghost image formation preventing device. In this embodiment, a light shield plate 70 having an aperture 70a is disposed immediately in front of the incident surface 13a of the Porro prism 13 to prevent off-field light bundle 60 from entering into the Porro prism 13. Only the light which is passed through the aperture 70a is allowed to enter into the Porro prism 13. The above described off-field light bundle 60, shown by a two-dot chain line in Figure 6, has a greater adverse effect on the field of view of the sighting telescope 20 as the optical path

length from the incident surface 13a to the first reflection surface 13b is shorter. To prevent this problem from occurring, in the first embodiment shown in Figures 9 and 10, the aperture 70a of the light shield plate 70 is shaped to be asymmetrical with respect to the optical axis 13X as shown in Figure 10, while the light shield plate 70 is provided, immediately above the substantially-circular shaped aperture 70a, with a light shield portion 70b which makes the shape of the aperture 70a imperfect circle. With the light shield portion 70b, a radial length R1 (see Figure 10) of the aperture 70a from the optical axis 13X to a side of the aperture 70a (the upper side as viewed in Figures 9 and 10), where the optical path length between the incident surface 13a and the first reflection surface 13b in the horizontal direction as viewed in Figure 9 is the shortest, is shorter than a radial length R2 from the optical axis 13X to the other side (the lower side as viewed in Figures 9 and 10) of the aperture 70a where the optical path length between the incident surface 13a and the first reflection surface 13b in the horizontal direction as viewed in Figure 9 is the longest. In other words, an area of the aperture 70a above a horizontal line intersecting the optical axis 13x at right angles is smaller than the remaining area of the aperture 70a below the horizontal line.

Figures 11 and 12 show the second embodiment of the ghost image formation preventing device. In this embodiment, the Porro prism 13 includes a first prism 13-1 having the incident surface 13a and the first reflection surface 13b, a second prism 13-2 having the second and third reflection surfaces 13c and 13d, and a third prism 13-3 having the fourth reflection surface 13e and the exit surface 13f. The first prism 13-1 and the third prism 13-3 are each cemented to the second prism 13-2. The Porro prism 13 is provided, on a common edge of the cemented surface of the first prism 13-1 and the second prism 13-2, with a recessed portion so that it is positioned in an optical path of the off-field light bundle 60. In the embodiment shown in Figure 12, a recessed portion 81 is formed on the first prism 13-1. As shown in Figure 13, a recessed portion 81′ corresponding to the recessed portion 81 can be formed on the second prism 13-2. The recessed portion may be formed on both of the first prism 13-1 and the second prism 13-2.

Figures 14 and 15 show the third embodiment of the ghost image formation preventing device. The third embodiment is the same as the above described second embodiment except that the Porro prism 13 is provided, on a common edge of the cemented surface of the first prism 13-1 and the second prism 13-2, with a beveled surface

instead of the recessed portion of the second embodiment. In the embodiment shown in Figure 15, the beveled surface 82 is formed on the first prism 13-1 along the edge of the cemented surface, i.e. the edge of the first prism 13-1 is beveled. As shown in Figure 16, a beveled surface 82′ corresponding to the beveled surface 82 can be formed on the second prism 13-2.

According to each of the second and third embodiments, the off-field light bundle 60 which reaches the recessed portion 81 (81′) or the beveled surface 82 (82′) after being reflected by the first reflection surface 13b does not proceed further therefrom, and therefore does not reach the AF sensor unit 50 or the eyepiece lens 15. It is preferable that the surface of each of the recessed portion 81 (81′) and the beveled surface 82 (82′) be formed as a matt surface, e.g., coated with a matt coating.

Figures 17 through 18 show the fourth embodiment of the ghost image formation preventing device. In this embodiment, the first prism 13-1 is shaped to extend forward (leftward as viewed in Figure 17) so that the incident surface 13a becomes closer to the focusing lens 12. With this structure, the off-field light bundle 60 which is reflected by the first reflection surface 13b is not incident on the second reflection surface 13c, but exits from the bottom of the forwardly-extended portion

of the first prism 13-1. The bottom surface of the forwardly-extended portion of the first prism 13-1 can be coated with a matt coating so as to reflect, diffuse or absorb the incident light thereon. As is clearly shown in Figure 17, the first prism 13-1 of this embodiment is formed to extend toward the focusing lens 12 so that the respective upper ends of the incident surface 13a and the first reflection surface 13b are not connected to each other but are apart from each other by a distance d.

Each of the above described first through fourth embodiments can be combined with another one or more embodiments if necessary. Furthermore, the Porro prism 13 can be provided, on each bonding surface among the first through third prisms 13-1, 13-2 and 13-3, with a light shield mask for preventing the off-field light bundle from entering the field of view of the sighting telescope 20. Note

Figures 19 through 27 show the fifth through eighth embodiments of the ghost image formation preventing devices. Each of the fifth through eighth embodiments is constructed so that the off-field light bundle 60 which is passed through a reflection surface of the Porro prism 13 does not reach the AF sensor unit 50.

Figures 19 through 21 show the fifth embodiment of the ghost image formation preventing device. In this embodiment, a semitransparent film is formed on the first

reflection surface 13b so as to serve as a beam splitter. Moreover, a rectangular light shield mask 90 (see Figure 20) having an elongated rectangular aperture 90a is fixed between the first reflection surface 13b and the incident surface 18a of the right-angle prism 18. Furthermore, a similar light shield mask 90 (see Figure 21) is fixed to the exit surface 18c. The light shield mask 90 provided between the first reflection surface 13b and the incident surface 18a reflects, absorbs or diffuses the incident light thereon. If the shape of the aperture 90a is determined so that only the two light bundles 11A and 11B (see Figure 4) which are respectively passed through two different pupil areas of the AF sensor unit 50 can pass through the aperture 90a, not only the off-field light bundle 60 but any other stray light can be cut off to ensure accuracy of the AF sensor unit 50. The hatched portions shown in Figures 20 and 21 show a portion (light interception member) other than the aperture 90a.

Figures 22 through 25 show the sixth embodiment of the ghost image formation preventing device. In this embodiment, a semitransparent film is formed on the second reflection surface 13c so as to serve as a beam splitter, and a right-angle prism 18′ is cemented to the semitransparent film formed on the second reflection surface 13c. Moreover, a light shield mask 90 (see

Figures 24 and 25) having an elongated rectangular aperture 90a, which is identical to that in the above described fifth embodiment, is fixed between the second reflection surface ~~13d~~ 13c and an incident surface 18d of the right-angle prism 18', while the same light shield mask 90 is fixed to an exit surface 18e of the right-angle prism 18'. Accordingly, it can be freely determined which of the reflection surfaces of the Porro prism 13 is formed as a semitransparent mirror. The light shield mask 90 can be positioned to correspond to the position of the semitransparent mirror and/or the position of the exit surface of the right-angle prism 18 or 18' that is cemented to the semitransparent mirror. The shape of the aperture 90a of the light shield mask 90 is identical to that of the light shield mask 90 shown in Figures 20 and 21.

Figure 26 shows the seventh embodiment of the ghost image formation preventing device. In this embodiment, a beam splitting prism 95 that is provided independently from the Porro prism 13 is disposed in front of the Porro prism 13. A semitransparent film 95a is formed on the beam splitting prism 95 to reflect part of the incident light on the semitransparent film 95a toward the AF sensor unit 50. The beam splitting prism 95 is provided on an exit surface 95b thereof (the upper surface as viewed in Figure 26) with a raised transparent portion 95c and a non-

transparent peripheral portion 95d whose surface is formed as a matt surface (e.g., coated with a matt coating).

Figure 27 shows the eighth embodiment of the ghost image formation preventing device. This embodiment is to the same as the seventh embodiment shown in Figure 26 except that the beam splitting prism 95 of the eighth embodiment is provided on an exit surface 95b thereof (the upper surface as viewed in Figure 27) with a light shield mask 90 (see Figure 28) having the elongated rectangular aperture 90a, which is to the same as that in the above described each of fifth and sixth embodiments, not with the raised transparent portion 95c and the non-transparent peripheral portion 95d. In Figure 28, the hatched portion shows a portion (light interception member) other than the aperture 90a.

In the seventh embodiment shown in Figure 26, the shape of the raised transparent portion 95c can be determined to correspond to the shape of the elongated rectangular aperture 90a of the light shield mask 90. According to each of the seventh and eighth embodiments, the off-field light bundle 60 is effectively prevented from entering the AF sensor unit 50, which ensures accuracy of the AF sensor unit 50.

Each of the above described first through eighth embodiments of the ghost image formation preventing

devices employs the Porro prism 13 as an erecting optical system. Figures 29 through 32 show ninth through eleventh embodiments of the ghost image formation preventing device. Each of the ninth through eleventh embodiments employs a Schmidt prism 130, including a roof prism, shown in Figure 29 as an erecting optical system instead of the Porro prism 13. The Schmidt prism 130 has an incident surface 130a, fifth see pg 38 first through sixth reflection surfaces 130b through 130f and an exit surface 130g as shown in Figures 29 and 30. The fourth reflection surface is a roof surface. A semitransparent film is formed on the second reflection surface 130c so that it serves as a beam splitter. The incident surface 130a extends perpendicular to an optical axis 130X. The light incident on the incident surface 130a is reflected upwards by the first reflection surface 130b at an angle of 90 degrees. Part of the light reflected by the first reflection surface 130b is reflected by the second reflection surface 130c at an angle of 45 degrees in a direction toward the third reflection surface 130d (in a direction oblique and lower rightward as viewed in Figure 29). The light reflected by the second reflection surface 130c is reflected by the third reflection surface 130d at an angle of 90 degrees in a direction oblique and lower leftward as viewed in Figure 29. The light reflected by the third reflection surface 130d is

reflected by the fourth reflection surface 130e at an angle of 90 degrees in a direction toward the fifth reflection surface 130f (in a direction oblique and lower rightward as viewed in Figure 29). The light reflected by the fourth reflection surface 130e is reflected by the fifth reflection surface 130f at an angle of 90 degrees to exit from the exit surface 130g to proceed toward the AF sensor unit 50. The exit surface 130g and the third reflection surface 130dare defined on the same plane, and extend perpendicular to an optical axis 130Y2. The optical axis 130Y2 is parallel to the optical axis 130X. A specific surface of a beam splitting prism (a right-angle prism) 18 is cemented to the semitransparent film formed on the second reflection surface 130c. The light which is reflected by the first reflection surface 130b and is subsequently passed through the second reflection surface 130c proceeds toward the AF sensor unit 50 along an optical axis 130Y1.

Figure 30 shows the ninth embodiment of the ghost image formation preventing device. In this embodiment, a light shield plate 70 having an aperture 70a and a light shield portion 70b, which is similar to the light shield plate 70 shown in Figures 9 and 10, is disposed immediately in front of the incident surface 130a of the roof prism 130 to prevent the off-field light bundle 60 from entering

into the Schmidt prism 130.

Figure 31 shows the tenth embodiment of the ghost image formation preventing device. In this embodiment, a recessed portion 181 is provided in the roof prism 130 between the Schmidt prism 130 and the beam splitting prism 18 along an edge therebetween, and is positioned in an optical path of the off-field light bundle 60.

Figure 32 shows the eleventh embodiment of the ghost image formation preventing device. In this embodiment, a semitransparent film is formed on the second reflection surface 130c so as to serve as a beam splitter. Furthermore, a light shield mask 90 shown in Figure 33 having the elongated rectangular aperture 90a, which is to the same as that in the above described fifth or six embodiment, is fixed to the second reflection surface 130c to be positioned between the second reflection surface 130c and the incident surface 18a of the beam splitting prism 18. In Figure 33, the hatched portion shows a portion (light interception member) other than the aperture 90a.

In each of the ninth through eleventh embodiments of the ghost image formation preventing devices, the off-field light bundle 60 which is incident on the Schmidt prism 130 reaches neither the eyepiece 15 nor the AF sensor unit 50.

In each of the above described first through eleventh embodiments of the ghost image formation preventing devices, although the AF sensor unit 50 is a phase-difference detection type, the AF sensor unit 50 can be replaced with any other type such as a contrast detecting type. The present embodiment of the electronic distance meter can be incorporated in or attached to not only a total station, but also any other surveying instrument having a surveying telescope such as a theodolite. Furthermore, the erecting optical system is not limited to those in the above-described embodiments.

The present embodiment of the electronic distance meter performs a distance measuring operation in a manner such as described in the following description. In the first step, a surveyor (user) aims the sighting telescope 10 at the corner cube prism 17 so that the optical axis X of the sighting telescope 10 is generally in line with the corner cube prism 17, while viewing the corner cube prism 17 through a collimator (not shown) which is attached to the sighting telescope 10. In the second step, the surveyor depresses the AF start switch 44 to perform the aforementioned autofocus operation to move the focusing lens 12 to an in-focus position (in-focus state) thereof relative to the corner cube prism 17. In the third step, in a state where the sighting telescope 10 is in focus

relative to the corner cube prism 17, the surveyor adjusts the direction of the sighting telescope 10 so that the reticle (cross hair) 15 viewed through the eyepiece 15 is precisely centered on the corner cube prism 17 while looking into the eyepiece 15. In the fourth step, the surveyor depresses the distance-measurement operation start switch 45 to perform the aforementioned distance-calculating operation, wherein the calculated distance is indicated on the indicating device 42.

As can be understood from the foregoing, according to a ghost image formation preventing device of a surveying instrument to which the present invention is applied, a ghost image is prevented from being formed in the field of the sighting telescope optical system. Furthermore, in the case of the surveying instrument equipped with a focus detecting device, a focus detecting operation can be performed with a high degree of precision.

Obvious changes may be made in the specific embodiments of the present invention described herein, such modifications being within the spirit and scope of the invention claimed. It is indicated that all matter contained herein is illustrative and does not limit the scope of the present invention.